Rio Tinto

Finding better ways

Decarbonising the steel value chain

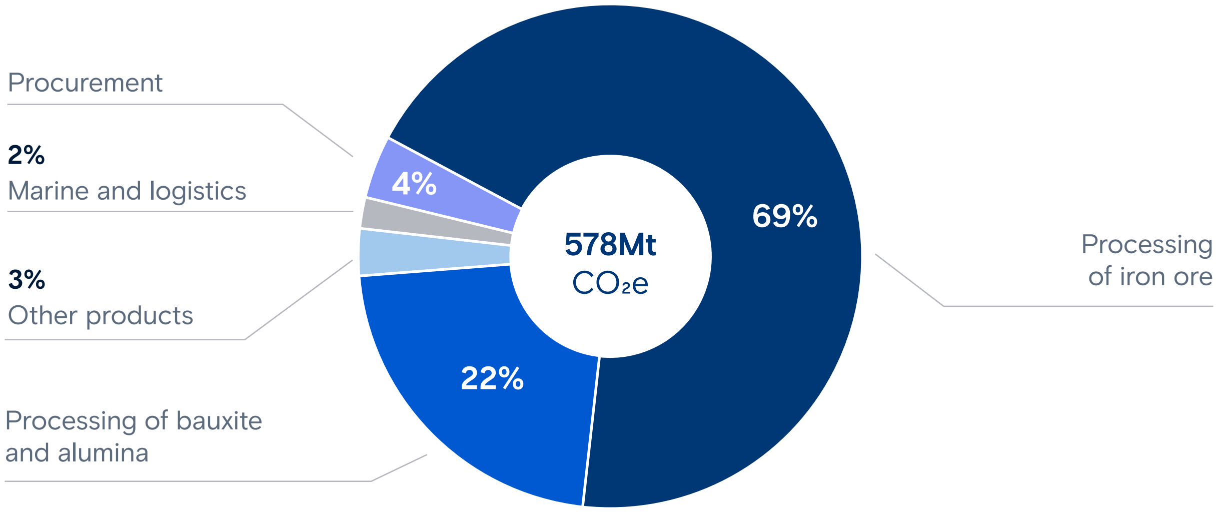
2024

As one of the world's largest iron ore producers, we have a key role to play in enabling decarbonisation of the steel value chain. Our global portfolio of low-, medium-, and high-grade iron ores, combined with our deep technical expertise and industry partnerships, uniquely position us to support decarbonisation of the steel value chain in the short and long term.

Our emissions

In 2023, our Scope 3 emissions were 578 million tonnes (Mt) CO_2e (equity basis), approximately 18 times higher than our Scope 1 and 2 emissions. The majority (69% or 400 Mt CO_2e) of these Scope 3 emissions stems from customers processing our iron ore into iron and steel.

Rio Tinto Scope 3 emissions, 2023 (Mt CO_2e)



Our approach to Scope 3 decarbonisation

Review of our customers' targets and their governments' commitments to reduce their emissions shows a trajectory for our Scope 3 emissions approaching net zero by around 2060. We are committed to partnering with our customers and suppliers to find better ways to help them achieve their targets a decade earlier – reaching net zero by 2050.

This means collaborating closely with customers, technology providers, governments, universities and other organisations to facilitate development of technologies for producing low-carbon[1] metals and minerals and helping shape demand for them.

We have not set an overall Scope 3 emissions target due to the limited direct influence we have on the decarbonisation activities of our customers, required maturation of technology and uncertainty around timing of technology adoption, and growth in renewable energy. Instead, we are committed to short- and medium-term actions that help drive decarbonisation across the value chains we participate in.

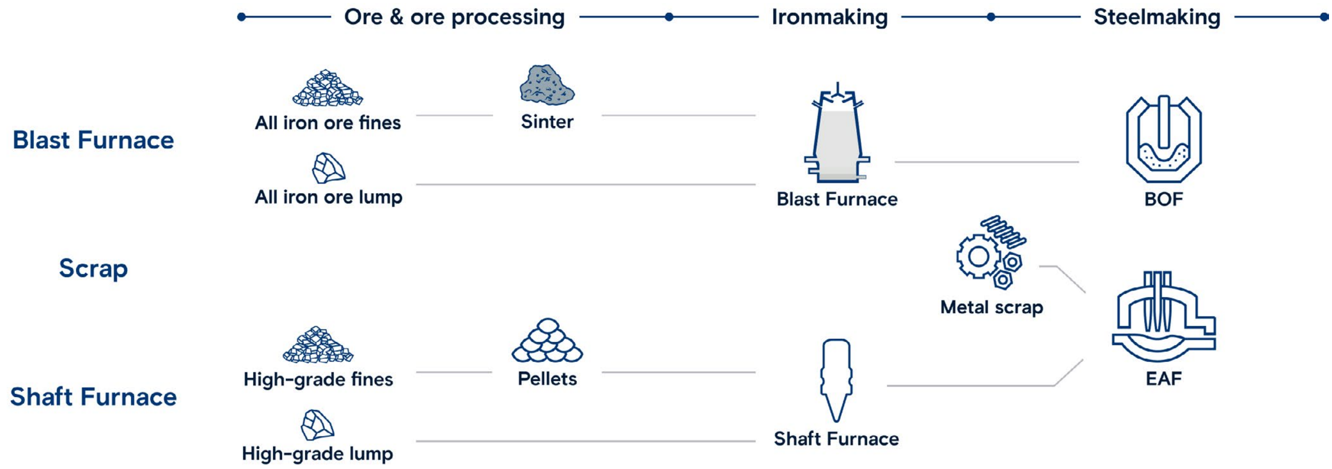
1. Low-carbon metals and minerals are defined as metals and minerals produced with low-CO_2 emissions

Cover | **3D model of the BioIron™ Research & Development Facility in Western Australia**

Steel: Why it matters and how it is made

Steel is the dominant metal used today and is essential for urbanisation, infrastructure development and the transition to low-carbon energy. In 2023, close to 2 billion tonnes of crude steel was produced globally, compared to approximately 100 million tonnes of aluminium and 25 million tonnes of copper. This scale, combined with the production processes used, resulted in the steel sector generating over 3 billion tonnes of CO_2 – or around 8% of global emissions.

Today's steelmaking pathways



The majority of steel value chain emissions are derived from the Blast Furnace–Basic Oxygen Furnace (BF-BOF) process, which accounted for approximately 70% of global steel production, and 85% of Asian[2] steel production, in 2023. The use of coal for heat and as a reductant makes it a carbon-intensive process, producing 2.3 tonnes[3] of CO_2 per tonne of steel. Most of our iron ore is placed with customers using the BF-BOF pathway, as it is economically advantaged and the only process that is technically and commercially proven for low- to medium-grade iron ore, such as that found in the Pilbara.

The Electric Arc Furnace (EAF) provides a low-carbon alternative to the BF-BOF steelmaking process and accounted for around 30% of global steel production in 2023. While the process is less carbon-intensive, it is less efficient at removing impurities compared to the BF-BOF, so must be fed by high-iron and low-impurity iron ore.

The EAF is fed by 2 sources:

- Scrap, which is the dominant source today. It can **reduce steelmaking carbon emissions by up to 95%** versus the BF-BOF when using renewable energy.
- Direct Reduced Iron (DRI), which is produced from the Shaft Furnace using natural gas, hydrogen, or a combination of both. This process can **reduce steelmaking carbon emissions by 50-90%** versus the BF-BOF. However, it requires high-purity iron ore pellets, like those from our Iron Ore Company of Canada (IOC) operations.

2. Asian BF-BOF steel production calculated using World Steel data. Data set includes China, Japan, South Korea, Taiwan and Other Asia. India is excluded for the purposes of calculation
3. World Steel Association, CO_2 emissions and energy intensity, 2022

Our strategy

Unlocking the most sustainable economic pathways for our iron ores

Today, we are working with numerous strategic partners across all components of the steel value chain to unlock the most sustainable and economic pathways for our iron ores. We have set near-term, action-oriented, and measurable targets in those areas where we believe we have the most agency and can support meaningful change.

In 2023, we spent US$28 million on steel decarbonisation initiatives and expect that to rise in 2024[4]

Our strategy is framed under 3 pathways, focused on different technologies and time horizons.

	Existing pathways	Emerging pathways	Future pathways
Focus area	Work with our customers to lower the carbon intensity of the Blast Furnace	Utilise our high-grade iron ores to accelerate the early proliferation of low-carbon DRI-EAF technologies	Unlock new low-carbon technologies for our low- and medium-grade iron ores
Targets	**Support our customers' ambitions to reduce their carbon emissions from the Blast Furnace by 20-30% by 2035[5]**	**Reduce our Scope 3 emissions from our IOC high-grade ores by 50% by 2035 relative to 2022 levels[6]**	**Commission the BioIron™ Pilot Plant by 2026[6,7]** **Commission a DRI (Shaft Furnace) + ESF (Electric Smelting Furnace) pilot plant by 2026 in partnership with a steelmaker[5]** **Finalise study on a beneficiation pilot plant in the Pilbara by 2026**

4. Delays in projects may result in some forecasted 2024 spend being pushed out to 2025
5. The support will be in the form of direct technical support and co-developing technology solutions
6. Subject to funding approval and technical feasibility
7. For more information about BioIron™, please see riotinto.com/news

Existing pathways

We anticipate the BF-BOF will remain the dominant steelmaking technology in Asia until around 2040. This is because the BF-BOF is the most economically viable technology, and there is currently no low-carbon technology that is technically and commercial proven for low- and medium-grade ores.

We expect Asian steelmakers to focus on optimising the Blast Furnace until economic low-carbon steelmaking technologies are industrially proven for low- and medium-grade ores. Any transition away from the BF-BOF will also have to overcome its economic advantage and justify the significant capital required to replace existing assets.

Recognising the importance of early-stage steel industry decarbonisation, we have committed to working with customers including Baowu, Shougang, Nippon Steel and POSCO to optimise their existing Blast Furnace technology, and to **support our customers' ambitions to reduce their carbon emissions by 20-30% by 2035**.

We plan to achieve this by partnering with customers, technology providers and universities on 4 key areas:

1. Optimising Blast Furnace burden to reduce the use of sinter[8]
2. Improving BF-BOF energy efficiency to minimise coal consumption
3. Improving slag utilisation to recycle heat and drive process efficiencies
4. Adopting carbon capture, utilisation and storage (CCUS) to abate carbon emissions

Partnership spotlight: Shougang

In 2022, we signed a Memorandum of Understanding (MOU) with Shougang to promote research, design, and implementation of low-carbon solutions for the steel value chain. Since then, we have progressed 2 projects with Shougang focused on low-carbon sintering technology and carbon capture and utilisation (CCU).

We invested US$1.5M over 2023-24 to support Shougang in commissioning a low-carbon sintering demonstration facility in July 2024. The facility has demonstrated **up to a 10% CO_2 reduction per tonne of sinter** at the facility and improved energy efficiency. If adopted by 50% of mills in China, this technology has potential to abate approximately 10 million tonnes per annum (Mtpa) CO_2, equivalent to 3 times the Scope 1 and 2 emissions of our Iron Ore operations.

Shougang low-carbon sintering facility, China

We have also committed US$3.5 million between 2023-25 to support Shougang's CCU ambition. Specifically, commissioning a 100m³ per hour CCU pilot in October 2024 and designing a 3,000m³ per hour pilot plant. Construction of the pilot plant is scheduled to commence in early 2025. Once operational, it is estimated that the 3,000m³ per hour pilot plant will capture approximately 10,000 tonnes CO_2 per year from the Blast Furnace offgas[9].

8. Including increased use of direct charge products such as lumps, pellets and DRI/HBI
9. The proportion of emissions abated by the CCU Pilot Plant will depend on how the captured emissions are utilised

Emerging pathways

As carbon prices rise in the future, we anticipate DRI technology will become increasingly cost-competitive with Blast Furnace ironmaking, which will support proliferation of low-carbon steelmaking via the EAF. We expect Atlantic steelmakers to lead the transition, with policies like the Carbon Border Adjustment Mechanism (CBAM) in Europe incentivising end-customers to increase demand for low-carbon steel.

Steelmakers are beginning to decarbonise today by transitioning to EAF operations. The Shaft Furnace will play a critical role in decarbonisation, providing DRI and Hot-Briquetted Iron (HBI) to mitigate limited volumes of high-quality scrap. However, several challenges currently exist when developing DRI/HBI capacity:

- Access to high-grade iron ore and pelletisation capacity
- Access to economic natural gas or hydrogen
- Ability to commit significant capital investment

We are supporting and accelerating the early development and proliferation of low-carbon steelmaking technologies by:

- Supplying high-grade iron ore from IOC, and eventually Simandou, to low-carbon projects
- Bringing together consortiums interested in decarbonising the steel value chain and investing in early-stage low-carbon ironmaking and steelmaking projects in energy-advantaged regions
- Supporting low-carbon projects by providing marketing services for the DRI and HBI they produce

We have set a target **to reduce our Scope 3 emissions from our IOC high-grade ores by 50% by 2035 relative to 2022 levels.**

We are undertaking studies in key regions with access to economic natural gas or renewable energy and in locations that are proximate to our high-grade ores.

We are also exploring the development of Fluidised Bed technology. The Fluidised Bed provides an alternative low-carbon ironmaking technology with similar abatement potential to the Shaft Furnace. While low-carbon Fluidised Beds using natural gas or hydrogen are yet to be proven at commercial scale, the technology is important because it does not require iron ore to be pelletised like the Shaft Furnace. Removing this processing step creates value for both steelmakers and iron ore suppliers as it removes capital and operating costs.

Partnership spotlight: GravitHy

In November 2024, we entered agreements with GravitHy – an industrial start up establishing 2 Mtpa production of ultra-low-carbon DRI in Fos-sur-Mer, France. As part of this collaboration, we will supply high-grade direct reduction iron ore pellets from our IOC operations, and manage the sales and marketing of GravitHy's ultra-low-carbon HBI.

Our IOC iron ore pellets will account for a significant portion of the iron ore supply to GravitHy's flagship plant. By becoming GravitHy's sales agent, we aim to prove demand for their ultra-low-carbon HBI and support project financing.

GravitHy's hydrogen-based DRI plant is expected to start production in 2028. The facility will feature ultra-low-carbon hydrogen production infrastructure, enabled by access to grid-connected nuclear power. By processing our iron ore with GravitHy, **emissions are reduced by up to 90%** compared to a typical BF-BOF pathway.

Potential GravitHy plant layout

"We are developing one of the most advanced ultra-low-carbon iron projects worldwide, designated by the French government as an 'Industrial Project of Major National Interest'. By combining our business ambitions, agility, and technological capabilities with Rio Tinto's global leadership in mining and steel decarbonisation, we are ensuring a solid sourcing and go-to-market strategy to help accelerate the development of this project."

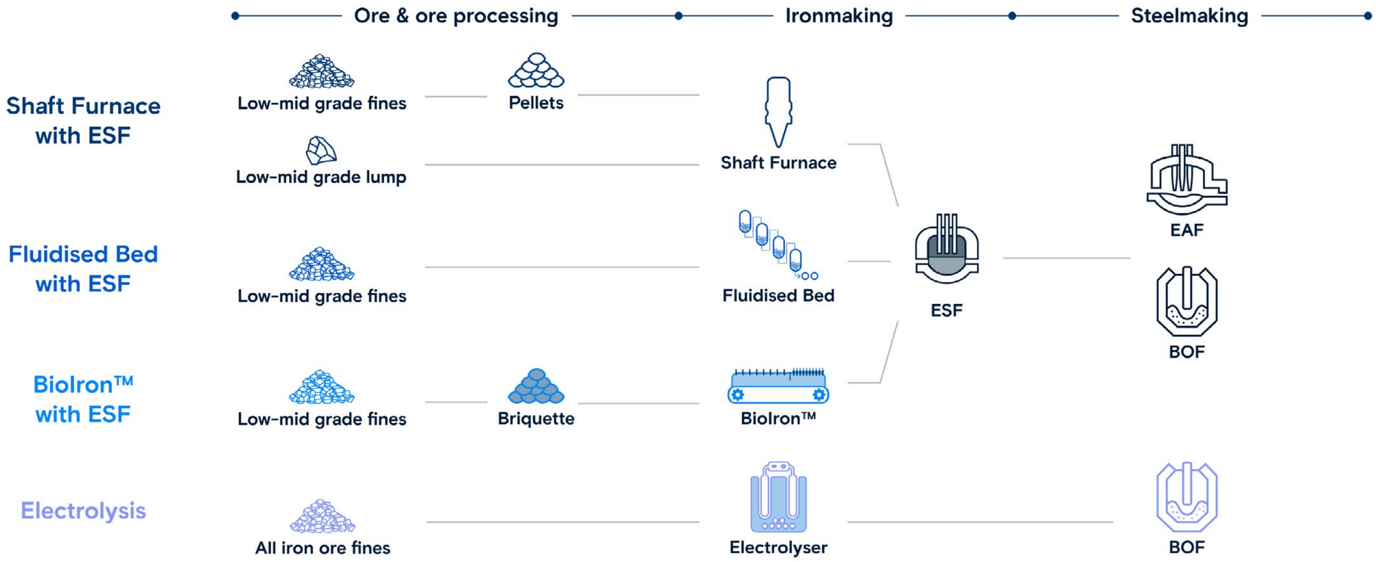
–José Noldin, GravitHy Chief Executive Officer

Future pathways

While low-carbon DRI-EAF steelmaking technologies are established for high-grade ores, like IOC and Simandou, it is not technically or commercially proven for Pilbara ores. With low- and medium-grade iron ores accounting for over 80% of global supply, decarbonisation of the steel industry depends on the development, commercialisation and proliferation of low-carbon technologies for these ores.

Our priority today is to develop economic low-carbon steelmaking technologies suited to low- and medium-grade iron ores, such as those in the Pilbara. Industrialisation and proliferation of these technologies will depend on access to economic low-carbon energy, as well as steelmakers' willingness to invest significant capital to replace existing infrastructure.

The 4 potential technologies we are focusing on are outlined in the figure below.



We are exploring opportunities to beneficiate[10] our ores, which would remove impurities before ironmaking. We're also advancing work to pelletise our ores, to improve their suitability to proven Shaft Furnace technology.

Rio Tinto's proprietary BioIron™ technology provides an alternative ironmaking process that does not require natural gas or hydrogen. Instead, the technology uses raw biomass and microwave energy to convert Pilbara iron ore into metallic iron[11].

Shaft Furnace, Fluidised Bed, and BioIron all require Electric Smelting Furnace (ESF) technology to transform low- and medium-grade ore into high-purity iron. The additional processing step melts the DRI using electricity and delivers similar efficient separation of the iron and mineral impurities to the Blast Furnace. Iron produced by this process is most suitable for the BOF steelmaking process, but can also be fed to an EAF, providing flexibility for steelmakers.

We are progressing our collaboration with BlueScope and BHP to build an ESF pilot facility in Australia, and with Baowu to build an ESF pilot facility in China.

10. Beneficiation is the process of upgrading ores physical and chemical properties through crushing, grinding and separation techniques to concentrate valuable minerals and remove impurities
11. Rio Tinto is aware of the complexities around the use of biomass supply and is working to ensure only sustainable sources of biomass are used in conjunction with this technology. See page 9 for further discussion

Lastly, Electrolysis uses renewable electricity and chemical processes to produce iron. Different variants are being developed – some operating at low temperature (<100°C) and others at high temperature (>1600°C). The technology is expected to be compatible with a wide range of ore types. While it is still in its early stages, we continue to monitor developments in this space.

As part of our commitment to working with partners to unlock low-carbon steelmaking pathways for low- and medium-grade iron ores, we have set 3 near-term targets:

1. Commission the BioIron™ Pilot Plant by 2026
2. Commission a DRI (Shaft Furnace) + ESF pilot plant by 2026 in partnership with a steelmaker
3. Finalise study on a beneficiation pilot plant in the Pilbara by 2026

Technology spotlight: BioIron Pilot Plant

BioIron™ is a proprietary Rio Tinto technology that has been developed over a decade of extensive research. The process uses raw biomass and microwave energy, instead of coal, to convert Pilbara iron ores into metallic iron, and has potential to **reduce carbon emissions by up to 95%** compared to the BF-BOF if combined with renewable energy and fast-growing biomass.

BioIron uses biomass from agricultural by-products (eg wheat straw and barley straw) or purpose-grown energy crops. The biomass is blended with iron ore and heated through combustion of biomass and microwaves. The microwaves are powered by renewable energy and only require a third of the electricity compared to green hydrogen-based ironmaking. It also only consumes a third to a quarter of raw biomass compared to other biomass char-based processes.

In 2022, a small-scale pilot plant project successfully proved BioIron as a low-carbon iron making process for Pilbara ores. We are now investing US$143 million to develop a 1 tonne per hour pilot plant in Western Australia that will further assess the effectiveness of BioIron. Commissioning is planned for 2026, representing the first time BioIron will be tested at a semi-industrial scale.

We continue to explore options for sustainably sourced biomass – ideally from nearby agricultural operations or from energy crops.

Raw materials for BioIron™ process: biomass, iron ores and fluxes

Spotlight: NeoSmelt – BlueScope, BHP and Rio Tinto ESF collaboration

In February 2024, we entered a framework agreement with BlueScope and BHP to jointly investigate the development of a DRI-ESF pilot plant in Australia. The project, called NeoSmelt, aims to develop the ESF, which is a critical technology for the economic production of low-carbon steel using low- to medium-grade Pilbara iron ores.

In December 2024, we announced that the Kwinana Industrial Area south of Perth, Western Australia, has been selected as the location for a pilot facility as part of a pre-feasibility study. The pilot plant would produce 30,000 to 40,000 tonnes of molten iron per year. It will initially use natural gas to reduce iron ore to DRI, but once operational, the project aims to use lower-carbon emissions hydrogen to reduce iron ore. **Reductions of up to 80%[12] in carbon emissions** are potentially achievable, compared to a typical BF-BOF.

NeoSmelt leverages BHP and Rio Tinto's deep knowledge of Pilbara iron ores with BlueScope's unique operating experience in ESF technology. Woodside Energy will also join the consortium as an equal equity participant and energy supplier, subject to finalising commercial arrangements.

The challenge of decarbonisation won't be solved alone. NeoSmelt is a great example of collaboration across the value chain to tackle decarbonisation of the steel industry.

Announcement of NeoSmelt pilot plant location, December 2024

12. Assumes utilisation of renewable energy to power the DRI-ESF facility and zero emissions hydrogen in the DRI plant. The remaining CO_2 emissions are from carbon required in the process of making liquid iron suitable for the basic oxygen steelmaking process

Accelerating steel industry decarbonisation: The role of government

While business has a vital role in managing the risks and uncertainties of climate change, governments can support these efforts by providing enabling frameworks, including policies and programs, that increase momentum towards shared net-zero goals. Decarbonisation of the steel sector will not happen in isolation; nations will need to work together. A range of different policies are needed to support research and development, first of a kind projects and larger scale deployment and commercialisation of low-carbon steelmaking.

Investment in research and development

A range of measures are necessary to support early movers to innovate and deploy low-carbon technology in hard-to-abate sectors. Incentives, investments from, and collaborations with government and research institutions are key to supporting industrial transitions and maintaining business competitiveness. Transformative, leading-edge research and development is complex, and trials of low emissions technology are expensive. Government policies, including tax credits and incentives, to meet this challenge are key. Government systems and regulations, including application approval periods, need to be streamlined and efficient, nimble enough to support the quantum of investment in research and development commensurate with the challenge and pace at which solutions are required.

Policies to support expanding industries or developing new industries, including low-carbon steel, that harness competitive energy advantages

The policy framework in respect of developing new low-carbon metals products and industries, including low-carbon ironmaking and steelmaking, outside of established markets needs to reflect the early-stage nature of these domestic industries and the significant capital intensity gaps between domestic production and established offshore processing.

Policies for these new low-carbon metals industries should focus in the short term on creating the conditions required to encourage the research and development activity that not only builds skills and knowledge but may contribute to reducing this cost gap.

Policies should underpin and support research and development of new and novel processing technologies which decarbonise the steel value chain, from iron ore to steelmaking, ensuring a prosperous future for Australian resources, both here in Australia and as inputs and exports to the global steel industry.

Implement effective carbon prices

Higher carbon prices are required to support the decarbonisation of hard-to-abate sectors, including steelmaking. A market-based price on carbon is the most effective way to incentivise the private sector to make low-carbon investments and drive down emissions. Higher carbon prices and other forms of support are necessary to address emissions from hard-to-abate sectors.

Effective climate policy should incentivise the private sector to invest in low-carbon technology without undermining the competitiveness of trade-exposed industries and shifting production, jobs and supply chains to countries with lower emissions standards (carbon leakage). Where there is significant regional variation in carbon prices, carbon border adjustment mechanisms (CBAM), or alternative policies, may be required to limit leakage, provided they are pragmatic, effective and equitable to minimise carbon leakage. However, carbon prices on their own are unlikely to be sufficient to drive large-scale widespread deployment of low-carbon steelmaking.

Policy to support research and development

Carbon pricing, on its own, might not be sufficient to transform the metals sector. Other policy tools are necessary to tackle emissions and simultaneously achieve objectives related to industrial policy. These can include:

- Grant funding, tax incentives and investment incentives to support research and development, innovation and first-of-a-kind projects
- Product standards and procurement obligations (such as minimum and rising requirements for low or zero carbon metal) that drive deployment of pre-commercial technology. Governments, government-funded businesses, and industry can continue to support the decarbonisation of steel by using their significant procurement and spending power to encourage suppliers to fast-track investment into the development of low-carbon steel.

RioTinto